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NOL RING TEST METHODS

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UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

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ABSTRACT: Methods have been developed for the evaluation of filament wound composite structures making use of NOL ring test specimens. A method of ring fabrication and techniques for determination of ring tensile strength and ring interlaminar shear strength have been standardized and are presented herein. References are also cited for flexural and compression tests now in use. These methods have all been found of value in making materials comparisons in research and development work and have also served as materials quality control techniques.

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This report presents information of the fabrication, tensile and shear testing of NOL rings. In addition, references are cited which present information on other testing techniques. The test methods described were developed at the Naval Ordnance Laboratory, and the experimental work leading to the development of the techniques was limited to the use of rings constructed with unidirectionally wound glass fiber reinforcement. Specimens were of the standard NOL ring dimensions, i.e., 14.60 cm x 14.91 cm x 0.635 cm wide for split disc tensile tests and 14.60 cm x 15.24 cm x 0.635 cm wide for all other tests. These tests have been found to be useful in providing a means for materials comparison and quality control studies on glass fiber reinforced plastics composites. Application of these procedures as standard methods of NOL ring evaluation will provide a basis for ready exchange of data and test results between testing facilities. The work has been supported by WepTask RREN-ST-204-212 and was carried out over the period from July 1962 to February 1964. The test methods as presented here are the result of a cooperative effort with section K of Committee D-20 of the American Society for Testing and Materials. Accordingly, Standard ASTM format has been used.

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Commander

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A. LIGHTBODY
By direction

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ACKNOWLEDGMENT

The assistance and encouragement of Dr. P. W. Erickson and Mr. S. P. Prosen in the preparation of the fabrication and test methods given herein is greatly appreciated. Mr. Prosen also aided in getting these methods before the A.S.T.M. for consideration as standards. Likewise, the work of Mr. J. Cuevas and Mr. E. T. Dyer and others in the evaluation of many many NOL rings by the various test methods is gratefully acknowledged.

INTRODUCTION

1. The use of filament winding techniques for the fabrication of plastics composite structures has grown at a fast pace in recent years. As is often the case, test methods and evaluation techniques have lagged behind the field of applications and general filament winding technology. A number of test methods of a non-standard nature have been used (see references (a) and (b)), but the need for standard techniques has resulted in efforts to develop a test specimen and test methods suitable for the evaluation of filament reinforced plastics composite structures.

2. At NOL, unidirectional fibers were first used in a research and development program for the evaluation of chemical finishes applied to heat cleaned glass fibers (references (c) and (d)). The finishes were applied to the glass to provide a uniform intermediate layer compatible with the resin system to be used in the composite structure. Several test specimen configurations were investigated, and it was concluded that a ring structure would be most useful for the proposed evaluation work. In addition, ring type specimens could be easily prepared and maximum control could be maintained on the winding parameters during fabrication.

3. The success achieved at NOL in the fabrication and evaluation of the ring led to its adoption by private industries in related fields of study, and resulted in the development of a variety of test methods. Comparison of these methods led to the conclusion that although the basic procedures were sometimes the same, specimen size, shape and testing parameters varied widely. To alleviate the problems associated with the dissemination of data between test facilities, NOL developed a series of ring test methods to be used as standards by the filament winding industries. This report serves to consolidate these test methods and techniques used in the present state-of-the-art. A recently developed method of NOL ring fabrication, a tensile test method and a shear test method are presented, as Appendices. In addition, references are cited for a number of test procedures now in use or recently used.

NOL RING FABRICATION AND TEST METHODS

4. A brief discussion of each of the fabrication and test methods used with the NOL ring is presented in the following paragraphs. For detailed information, the Appendices and references cited should be studied.

a. Fabrication. Appendix A presents a standardized technique for the fabrication of NOL rings. Use of this method requires the availability of a ring winding machine capable of controlling and monitoring fabrication parameters during the winding process. Variables requiring close control are discussed.

b. Tensile Testing. True tensile properties of rings were first determined at NOL by use of a hydraulic test device (reference (e)). The test specimen was placed in an annular cavity, an obturator or sealing ring was inserted, and the fixture was closed and pressurized until failure of the specimen occurred. This fixture was also used, with an extensometer attachment, for the determination of tensile modulus. There were two disadvantages inherent in its use: (1) the specimen could not be observed during pressurization and ultimate failure, and (2) loading and unloading the specimen required considerable time.

A split-disc tensile test method was then developed as a rapid means for determination of an apparent tensile strength for NOL rings. The method consists of placing the test specimen over the machined surfaces of a split steel disc and applying a load by means of a suitable test machine until failure of the specimen occurs. It is recognized that, due to bending moments set up at the plane of separation of the disc halves, a true tensile strength result is not obtained. For comparative purposes, however, this method of test is most satisfactory. It has now been standardized and is presented in full in Appendix B.

A standard test method for the determination of ring tensile modulus has not been prepared. One simple technique now in use consists of applying a load at two diametrically opposite points on the ring and measuring the amount of deflection which occurs. The result, which is essentially a flexural or bending modulus, is calculated by use of the following equation (see reference (f)):

$$E = \frac{0.1257 r_{ave}^3}{bd^3} \cdot \frac{P}{\Delta}$$

Where

E = modulus (kg/cm^2)

Δ = total deflection of head (cm)

P = total Load (kgs)

r = mean radius of ring (cm)

b = ring width (cm)

d = ring thickness (cm)

c. Flexural Testing. The flexural properties of NOL rings are determined by use of a four-point loading jig (reference (g)). A segment of the ring is supported near its ends and loaded on the concave surface at the center of its span. This test is a modification of the three-point loading test which has found intensive use with flat laminate specimens. It can also be used to determine the deflection of composite ring structures.

d. Shear Testing. A short-beam interlaminar shear test method recommended for use with NOL ring specimens is presented in Appendix C. The technique requires the use of ring segments, with a central load applied to the convex surface of the specimen until shear failure occurs interlaminarly. The same basic fixture, modified for application of a constant load to the test specimen, is used for determination of creep characteristics at various percentages of the ultimate load. This system may be used either for dry testing of specimens or for tests during submersion in water.

e. Compression Testing. The first compression test fixture utilizing the NOL ring specimen is discussed in reference (h). The fixture consists of two halves, analogous to the NOL split disc for tensile testing, and subjects the ring to a load on its outer diameter, compressing it until ultimate failure occurs. To determine the true compressive properties of a ring structure with a fixture of this type, it must be designed to either test a thick ring or to support the ring in such a manner as to prevent buckling. The fixture discussed in reference (h) was constructed so that buckling in the gap area was minimized.

The development of a test method and fixture providing for the evaluation of the true compressive properties of the NOL ring is discussed in reference (i). The device applies a mechanical radial load to the outer diameter of the test specimen by means of 72 rigid members, each of which compresses the ring at the same constant rate. The ring is restrained from buckling, since for buckling to occur, some of the members must move relative to all other members. This is physically

impossible without destruction of the test fixture. The method requires an entire ring as a specimen and provides information on both the compressive strength and the compressive modulus of the composite ring structure.

FUTURE NOL RING TEST METHODS

5. The compilation of cyclic fatigue data for characterization of the structural properties of plastics composite structures is becoming increasingly important. In addition to the test methods discussed and presented herein, techniques will shortly be developed for determination of the static and dynamic fatigue characteristics of NOL rings and ring segments.

6. It is proposed to submit specimens to torsional, tensile and compressive cyclic loads of varying frequencies and amplitudes. Tests will be carried out both dry and during or after submersion in water. The body of data collected by use of these fatigue test methods are expected to provide a clearer picture of failure mechanisms in plastics composite structures.

CONCLUSIONS

7. This report presents a method of fabrication, a tensile test method, and a shear test method which are intended for use in research and development studies to determine the properties of plastics composite structures. These three methods are being accepted by ASTM as standards for the making and testing of unidirectionally wound glass fiber reinforced structures.

8. References are also presented on several other test methods for filament wound composites. All of these techniques are of value in the collection of quality control data on materials being used in the fabrication of ordnance. They also provide a basis for the comparison of test results between testing and fabrication facilities.

9. Studies and development work were limited to the use of specimens machined to the standard NOL ring dimensions.

RECOMMENDATIONS

10. The test methods presented as Appendices to this report should be implemented whenever plastics materials properties are to be determined on NOL ring specimens. The referenced techniques which are currently in use should be employed whenever additional mechanical properties are required.

APPENDIX A

RECOMMENDED PRACTICE FOR FABRICATION OF RING TEST SPECIMENS ASTM DESIGNATION D _____

SCOPE

1. This recommended practice is intended for use in the fabrication of ring-type test specimens to be used in the evaluation of the mechanical properties of reinforcement and resins in a composite structure. The practice outlines the steps in the preparation of the test specimens including the final specimen machining where applicable. Three final ring configurations are included.

APPARATUS

2. The apparatus for fabrication of the ring test specimen shall consist of the following:

   a. Winding Machine - The winding machine may consist of any adequate superstructure on which components may be mounted for applying resin to the reinforcement, or mounting impregnated reinforcement, tensioning the reinforcement and collecting the wetted, tensioned material on a mold or mandrel of the desired size.

   b. Tension Measuring System - Any suitable device for measurement of the tension applied to the wetted reinforcement may be used. The device must be capable of measuring the tension accurately to within $\pm$ 5%.

   c. The single ring fabrication mold on which the wetted reinforcement is collected shall be constructed as shown in Figure 1. For cylinder fabrication from which rings are to be cut, a mandrel with the proper diameter fitted to a suitable winding machine shall be used to collect the wetted reinforcement. The surfaces of the mold or mandrel which contact the ring specimens shall be coated or otherwise treated to prevent sticking of the ring or cylinder in the mold or on the mandrel.

   d. Curing Ovens - Ovens having adequate range in temperature to produce a fully cured specimen shall be available for use. Control of the curing-post curing temperature to within $\pm$ 5° C ($\pm$ 9° F), is required.

STORAGE AND CONDITIONING OF COMPONENTS

3. Glass rovings and yarns for use in fabrication of ring test specimens shall be stored in a dry place, not subject to temperature extremes, or as specified by the glass producer. Prior to use, the rovings shall be conditioned according to ASTM D-618.

4. Resins to be used in the fabrication of ring test specimens shall be stored in closed containers at a temperature as specified by the supplier. In addition, no resin shall be used which has been stored for a period in excess of the shelf life recommended by the supplier. Prior to fabrication of the test specimen, the resin shall be heated as necessary to provide sufficient lowering of the viscosity to produce good wetting of the reinforcement strand.

5. Preimpregnated materials received for the preparation of ring test specimens shall be stored in a closed container at a temperature as recommended by the supplier. Before winding, it shall be removed from a storage and conditioned as recommended by the supplier or in accordance with ASTM D-618.

PROCEDURE FOR DRY REINFORCEMENT

6. Figure 2 is a schematic diagram of the system for wetting, tensioning, and collecting the reinforcement.

   a. Mounting reinforcement packages - The reinforcement package shall be mounted in a convenient location within the superstructure of the winding machine. Sufficient braking of the axle of the package to prevent free-wheeling must be provided. This should be a minimum tension.

   b. Application of the Resin - The reinforcement leaving the package shall pass immediately into the resin bath. The resin bath shall be heated sufficiently to lower the resin viscosity to a workable range. As the reinforcement is pulled from the resin bath, excess resin shall be removed by any convenient method which results in a minimum amount of fraying or breakage of the reinforcement.

   c. Tensioning - After leaving the resin bath, the reinforcement shall be passed over a pulley or a series of pulleys, which are adequately braked to impart the desired tension to the fibers. The tension may be monitored, by any convenient method, either periodically or continuously during the winding operation. Deviation from the mean

tension shall be limited to ± 5% from start to finish of the winding of a test specimen. The diameter of the tension pulley (s) shall be a minimum of 3.0 inches. Larger sizes should be used when available. Care must be taken that no slippage of the strand occurs over the pulley (s).

d. Level-winding - The wetted reinforcement shall next pass through a level-winding guide and onto the mold. The guide shall be geared to the mold or mandrel or shall follow a cam in such a manner that each revolution of the mold or mandrel will be accompanied by a precession of the guide by an amount equivalent to one strand width.

e. Collecting the reinforcement - The wetted reinforcement strand shall be collected on a mold or mandrel which is mounted on the axle of a variable speed drive. The strand velocity through the resin bath shall be constant and shall be slow enough to give good wetting of the reinforcement with the resin. An adequate mold release agent shall be applied to the mold or mandrel before winding is begun to assure easy removal of the specimen after fabrication. Specimens which will be tested without machining the surface will be wrapped to a thickness as indicated for Type "B" specimen, Figure 3. The Type "A" and Type "C" specimens in Figure 3 shall be built up to a thickness beyond that required for finished thickness. Upon completion of the winding process, the strand shall be secured in such a manner as to retain the tension before cutting the strand and removing the mold or mandrel from the winding machine.

f. Curing - The molds or mandrel shall be transferred to an oven and the resin polymerized in the manner prescribed by the literature (Note 1).

g. Removing the Rings from the Mold or Mandrel - The ring specimens shall be removed from the molds or mandrel in such a manner that delamination or other damage to the surfaces does not occur. An arbor press may be used to apply force to separate the mold parts in the single ring process if required.

<u>NOTE 1</u> Excess resin on the surface of the type "B" specimen should be removed if possible during cure.

h. Preparation of specimens for Testing.
   1) Width - The width of the type "A", "B", and "C" specimens shall be molded or machined to correct width.

2) Thickness - The thickness of the type "B" specimens will not be machined. The thickness of the type "A" and "C" specimens will be machined to the correct wall thickness.

3) The dimensions of the finished test specimen are given in Figure 3. Following the machining operation, the specimen may be submitted to test or may be cut into flexural or horizontal shear specimens as desired. When cutting these specimens from the ring, care shall be taken that all cut surfaces are parallel to the radius of the ring.

PROCEDURE FOR PRE-PREGS

7. The procedure which shall be used for the preparation of ring test specimens from preimpregnated material shall be identical to that described for dry roving, except that paragraph 6 (b) shall be omitted (See Figure 4).

REPORT

8. The report should include the following:

(1) Complete identification of all components in the rings fabricated; including type, source, form of the resin system, reinforcement, or preimpregnated material. It should also include the history of the material including, but not limited to, age and storage conditions.

(2) Complete description of conditions under which rings were fabricated, including temperature and relative humidity.

(3) Complete description of impregnation method.

(4) Resin wiping technique

(5) Tension

(6) Rate of winding.

(7) Any special equipment or methods utilized.

(8) Type of specimen fabricated, single or cylinder.

(9) Mold materials used.

(10) Complete cure procedure.

(11) Date of fabrication.

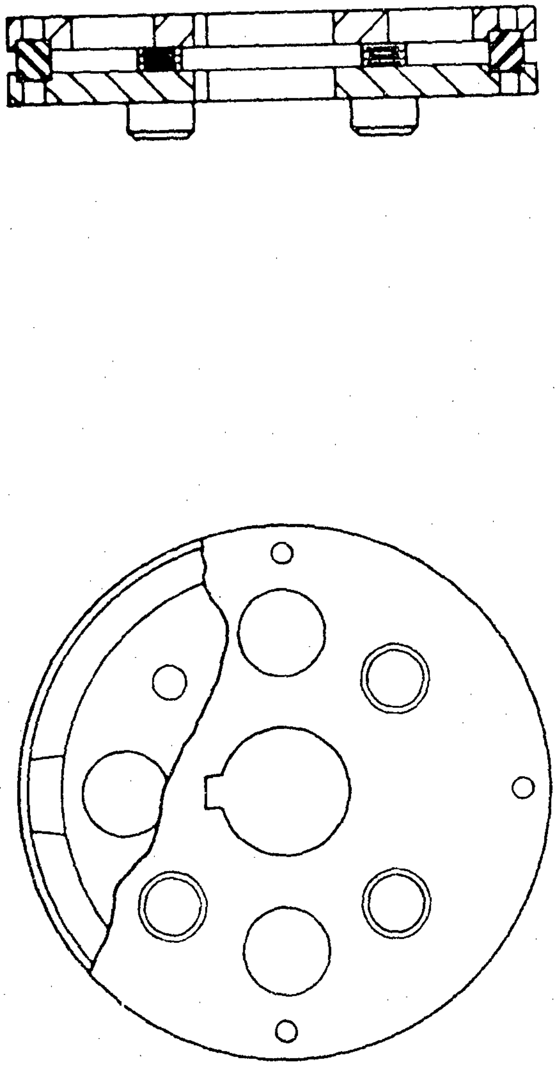


FIG. A-1 SUGGESTED SINGLE RING MOLD

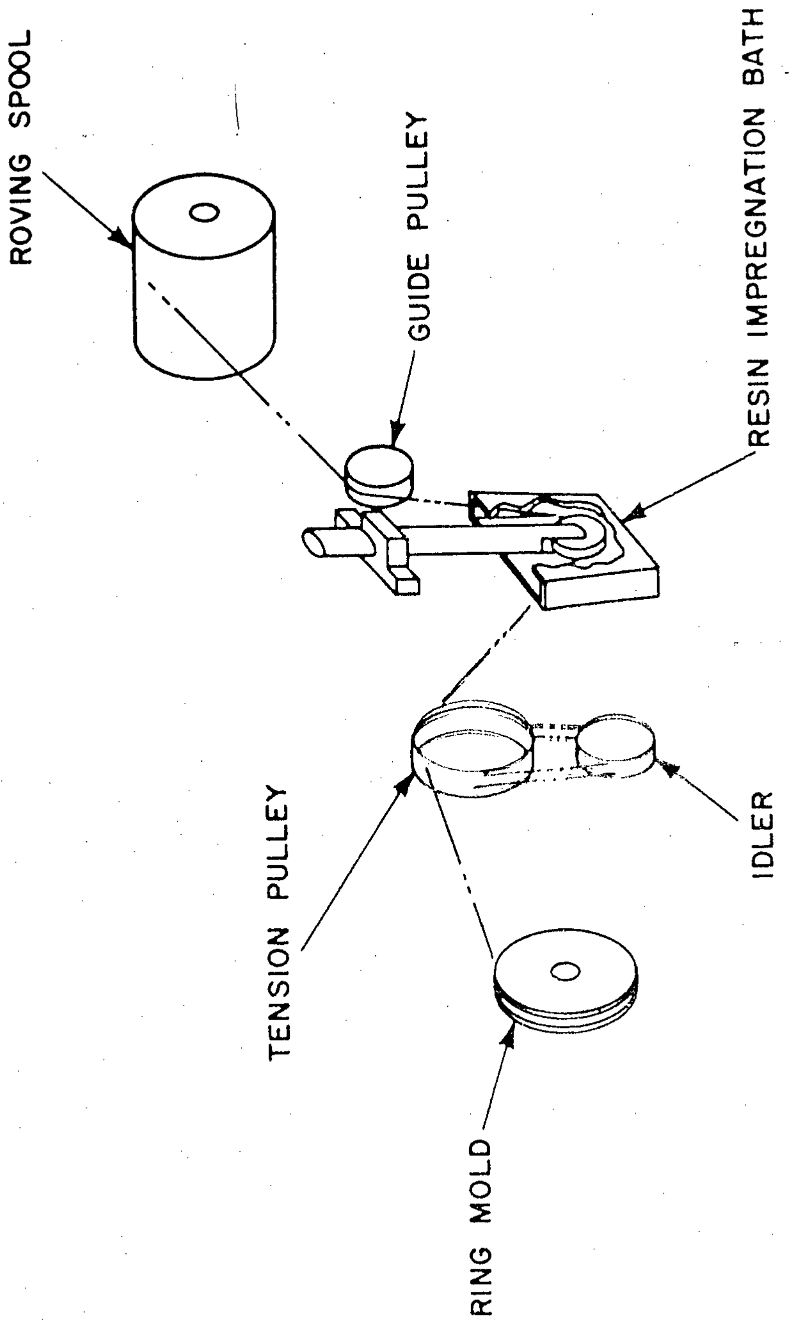
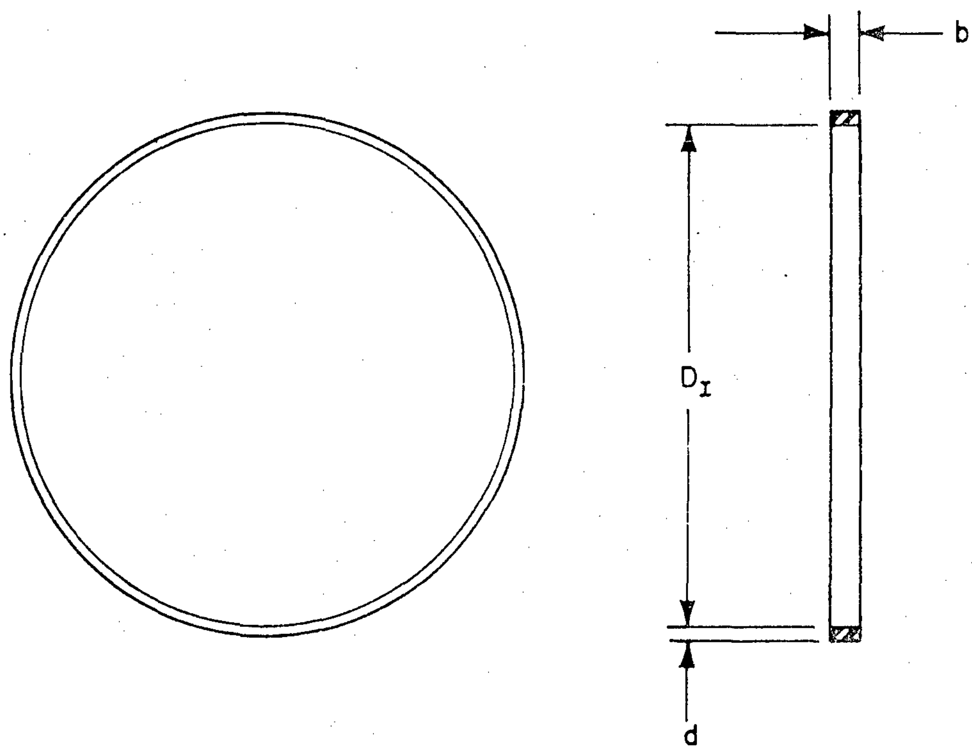


FIG. A-2 SCHEMATIC DIAGRAM OF WET ROVING RING WINDING APPARATUS



SPECIMEN DIMENSIONS			
TYPE OF SPECIMEN	D_I INSIDE DIAMETER	b WIDTH	d WALL THICKNESS
A	146.05 ±0.051 MM (5.750 ±0.002 IN.)	6.35 $^{+0.127}_{-0.000}$ MM (0.250 $^{+0.005}_{-0.000}$ IN.)	1.52 ±0.051 MM (0.060 ±0.002 IN.)
B	146.05 ±0.051 MM (5.750 ±0.002 IN.)	6.35 $^{+0.127}_{-0.000}$ MM (0.250 $^{+0.005}_{-0.000}$ IN.)	1.52 ±0.254 MM (0.060 ±0.010 IN.)
C	146.05 ±0.051 MM (5.750 ±0.002 IN.)	6.35 $^{+0.127}_{-0.000}$ MM (0.250 $^{+0.005}_{-0.000}$ IN.)	3.18 ±0.051 MM (0.125 ±0.002 IN.)

FIG. A-3 RING TEST SPECIMEN

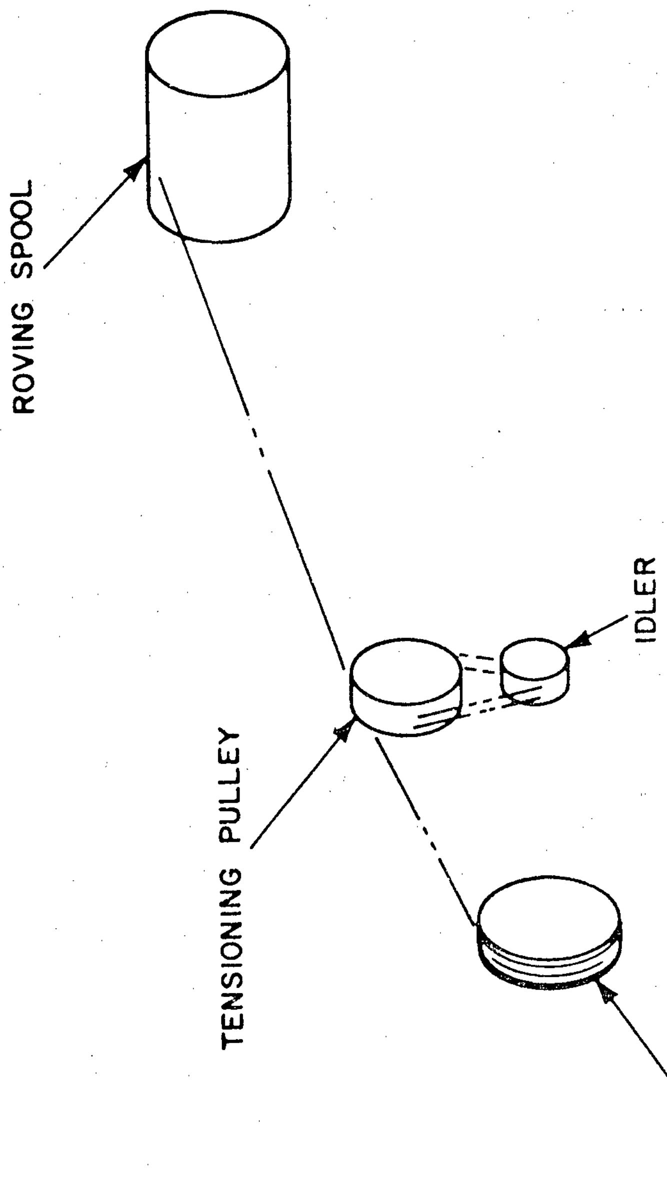


FIG. A-4 SCHEMATIC DIAGRAM OF PRE-PREG ROVING WINDING SYSTEM

APPENDIX B

METHOD OF TEST FOR APPARENT TENSILE STRENGTH OF PARALLEL REINFORCED PLASTICS BY SPLIT DISC METHOD
ASTM Designation D ______

SCOPE

1. This method is intended for use in determining the comparative apparent tensile strength of essentially parallel wound reinforced plastic rings utilizing a split disc test fixture, when tested under defined conditions of pre-treatment, temperature, humidity, and test machine speed. The method is applicable to all types of parallel fiber reinforcement.

PRINCIPLE OF METHOD

2. Apparent Tensile Strength - The test specimen (Figure 1, type A with controlled width and thickness and type B with controlled width) is loaded on the suggested self-aligning split disc test fixture (Figure 2) which applies tensile stress to the test ring. An apparent tensile strength is obtained in this test due to a bending moment imposed during test at the split between the split disc test fixture. This moment is induced by the change in contour of the ring between the two disc sections as they separate. The test specimen is designed to minimize the effect of this bending moment.

SIGNIFICANCE

3. Split disc tension tests, properly interpreted, provide reasonably accurate information with regard to the apparent tensile strength of reinforced plastics when employed under conditions approximating those under which the tests are made.

Tensile tests may provide data for research and development, engineering design, quality control, acceptance or rejection under specifications, and for special purposes. The test cannot be considered significant for applications differing widely from the load-time scale of the standard test. Such applications require suitable tests such as impact, creep, and fatigue.

APPARATUS

4. (a) Micrometers - Suitable ball type micrometers, reading to at least 0.025 mm (0.001 in), for measuring the width and

thickness of the test specimens.

(b) Testing Machine - A universal testing machine of the constant-rate-of cross-head movement type and comprised essentially of the following:

(1) Drive Mechanism - A drive mechanism for imparting to the crosshead a uniform controlled velocity with respect to the base, this velocity to be regulated as specified in Section 8.

(2) Load Indicator - A load-indicating mechanism capable of showing the total tensile load carried by the test specimen. This mechanism shall be essentially free from inertia-lag at the specified rate of testing and shall indicate the load with an accuracy of $\pm$ 1 per cent of the indicated value. The accuracy of the testing machine shall be verified in accordance with the tentative methods of verification of testing machines (ASTM designation E-4.)

(c) Test fixture - A suggested test fixture is shown in Figure 3. The supports for holding the tensile fixture shall be self-aligning, that is, they shall be attached to the fixed and movable member of the test machine, respectively, in such a manner that they move freely into alignment as soon as any load is applied, so that the direction of the applied pull is directly perpendicular to the split axis of the tensile fixture.

(d) Conditioning Apparatus - Apparatus for maintaining the standard laboratory atmospheric conditions of 23 $\pm$ 1° C. (73.4 $\pm$ 1.8° F) and 50 $\pm$ 2% relative humidity for conditioning prior to test, as defined in Procedure A of the Standard Methods of Conditioning Plastic Electrical Insulating Materials for Testing, A.S.T.M. Designations D-618, shall be used, except 24 hours will be the minimum time period.

TEST SPECIMEN

5. (a) The rings used in this test method shall be fabricated per A.S.T.M. D _______ "Tentative Recommended Practice for Fabrication of Ring Specimens".

The test specimen will conform to the dimensions shown in Figure 1. Specimen type A has the dimensions of the width and thickness controlled, and type B has the width controlled but the thickness is maintained as wound and cured. All surfaces of the specimen shall be free from visible flaws, scratches, or imperfections.

(b) Number of test specimens - The number of test specimens is optional, however a minimum of five specimens is recommended to obtain a reliable average for a sample.

CONDITIONING

6. (a) Plastic materials may be preconditioned for testing under "Standard" atmospheric conditions of 23 $\pm$ 1° C (73.4 $\pm$ 1.8° F) and 50 $\pm$ 2% relative humidity, as defined in procedure A of the Standard Methods of Conditioning Plastic Electrical Insulation Materials for Testing (A.S.T.M. Designation D-618) except 24 hours will be the minimum time period.

(b) Special conditioning procedures may be used by agreement between cooperating laboratories.

SPEED OF TESTING

7. (a) Speed of testing is velocity of separation of the two members of the testing machine when running idle (under no load).

(b) The standard speed of testing shall be 2.54 millimeters per minute (0.10 inches per minute).

PROCEDURE

8. (a) Mark the ring at two randomly selected points 180° apart. In marking the specimen, a soft wax crayon or india ink shall be used. Scratching the surface of the specimen can cause weakness and premature fracture and should be avoided.

(b) Measure the width and thickness of the randomly selected points to the nearest 0.025 millimeter (0.001 inch) using a ball type micrometer. Record the single width and thickness from the point whose product gives the minimum cross-sectional area.

(c) Mount the test specimen on the outside periphery of the split disc test fixture (Figure 2) with the randomly selected points at the split in the fixture. Lubrication of the periphery is optional. The test fixture should be designed to positively align the test ring on the test fixture so that it is centered on the line joining the points of attachment of the fixture to the test machine.

(d) Set the speed control at 2.54 mm/min (0.10 in/min) and start the test machine.

(e) Record the maximum load carried by the specimen during the test (usually this will be the load at the moment of rupture).

(f) Determine resin content percent by weight of specimen.

CALCULATIONS

9. (a) The apparent tensile strength of the composite shall be calculated using the following equation and reported to three significant figures, an optional calculation of the apparent tensile strength of reinforcement is given in Note 1.

$$f_t \text{ com} = \frac{P_B}{2\, A_{min}}$$

where:

f_t com = Apparent tensile strength of composite in kilograms per square centimeter (pounds per square inch)

P_B = Breaking load in kilograms (pounds)

A_{min} = Minimum cross-section area of the two measurements = (d) (b), square centimeters (square inches)

d = Thickness at minimum area, centimeters (inches)

b = width at minimum area, centimeters (inches)

(b) For each series of tests, the arithmetic mean of all values obtained shall be calculated to three significant figures and reported as the "average value" for the particular property in question.

(c) The standard deviation shall be calculated as follows and reported to two significant figures:

$$s = \sqrt{\frac{\Sigma(x^2 - \bar{x}^2)n}{n-1}}$$

where: s = estimated standard deviation
x = value of single observation
n = number of observations
$\bar{x}$ = arithmetic mean of set of observations

REPORT

10. The report should include the following:

(1) Complete identification of the material tested, including type source, manufacturer's code number, form, principal dimensions, and previous history.

(2) Fabrication procedure

(3) Type specimen used

(4) Thickness and width of minimum cross-sectional area.

(5) Conditioning procedure used

(6) Atmospheric conditions in test room

(7) Number of specimens tested

(8) Rate of crosshead motion

(9) Apparent composite tensile strength of each specimen, and average calculated and reported to three significant figures.

(10) Standard deviation (estimated) of the sample shall be calculated and reported to two significant figures.

(11) Average resin content percent by weight of specimens

(12) Date of test.

<u>NOTE 1: OPTIONAL CALCULATION - APPARENT TENSILE STRENGTH OF REINFORCEMENT</u>

To compare composites that have differing resin contents, an apparent tensile strength of reinforcement may be calculated from resin content using the following formulae. These assume that the resin matrix carries no load, and require that the specific gravities of composite material and of reinforcement material be known.

$$f_t \text{ reinf.} = \frac{P_B}{2\ A_{\text{reinf.}}}$$

$$A_{\text{reinf.}} = A_{\text{min}} \times G_{\text{comp.}} \times \frac{(100 - r)}{(G_{\text{reinf.}})}$$

where: f_t reinf. = Apparent tensile strength of reinforcement in kilograms per square centimeter (pounds per square in.)

P_B = Breaking load in kilograms (pounds)

A_{min} = Minimum composite cross-section area of the two measured, in square centimeters (square inches)

$A_{reinf.}$ = Area of reinforcement only (excluding resin matrix) in square centimeters (square inches)

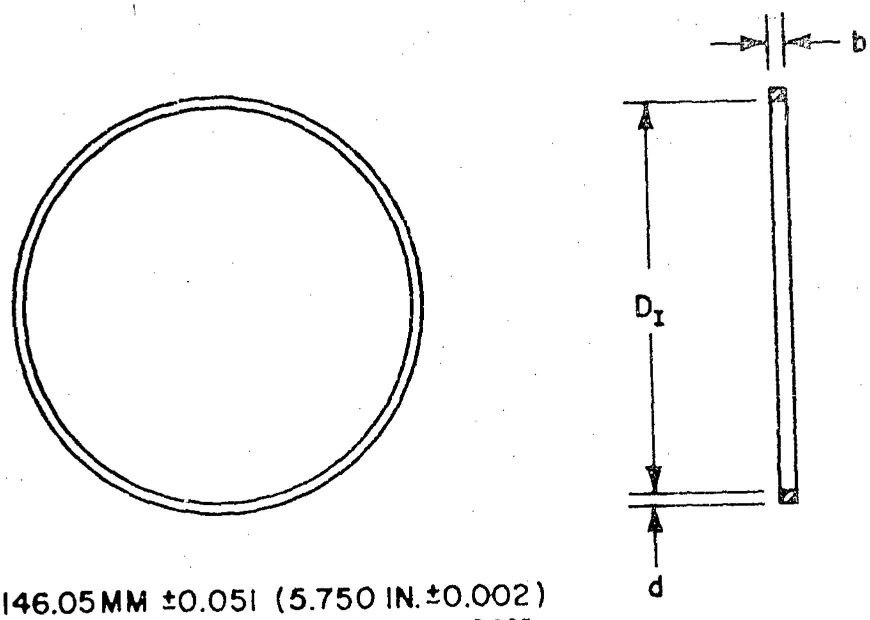
r = Resin content, weight percent

$G_{reinf.}$ = Specific gravity of reinforcement material

G_{comp} = Specific gravity of composite material

Recommended values for specific gravity of two commonly used glass reinforcement materials are:

"E" Glass - 2.55
"S" Glass - 2.485



D_I = 146.05 MM ±0.051 (5.750 IN. ±0.002)

b = 6.35 MM $^{+0.127}_{-0.000}$ (0.250 IN. $^{+0.005}_{-0.000}$)

TYPE "A" d = 1.52 MM ±0.051 (0.060 IN. ±0.002)

TYPE "B" d = 1.52 MM ±0.254 (0.060 IN. ±0.010)

FIG. B-1 RING TEST SPECIMEN

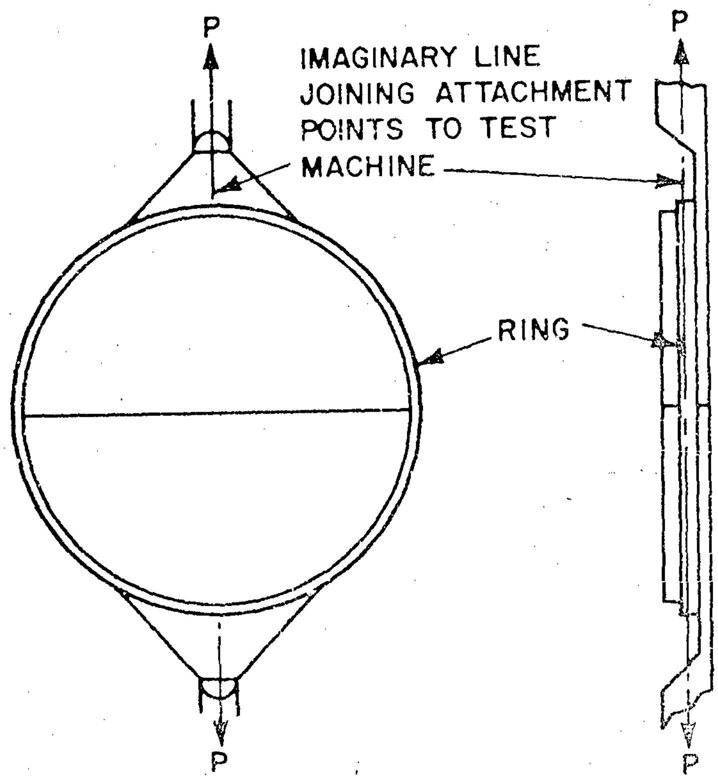


FIG. B-2 SPLIT DISC TEST SPECIMEN UNDER LOAD

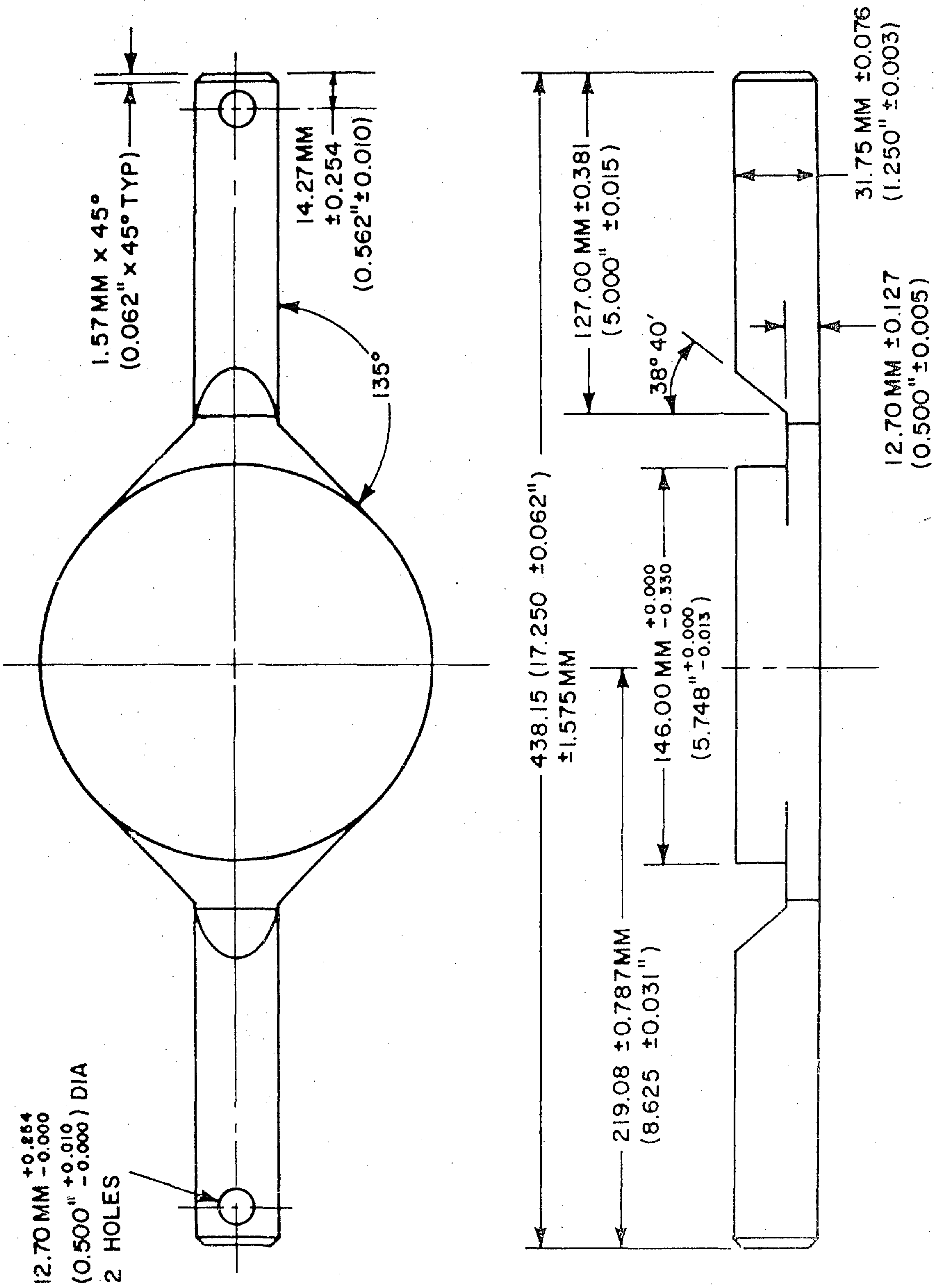


FIG. B-3 SUGGESTED SPLIT DISC TENSILE TEST FIXTURE

APPENDIX C

METHOD OF TEST FOR HORIZONTAL SHEAR STRENGTH BY SHORT BEAM METHOD ASTM Designation D _____

SCOPE

1. This method covers the procedure for determining the horizontal shear strength by a short beam method of parallel fiber reinforced plastics in the form of segments cut from a ring-type specimen. The method is applicable to all types of parallel fiber reinforcement.

PRINCIPLE OF METHOD

2. Horizontal Shear. - The test specimen (Fig. 1) is center loaded on the convex side (Fig. 2). The specimen ends rest on two freely moving supports, the load being applied by means of a loading nose directly centered on the midpoint of the test specimen. A workable self-centering jig is shown in Fig. 3.

SIGNIFICANCE

3. Horizontal shear strength determined by this method is especially useful for quality control and specification purposes. This test provides information on the relative effectiveness of finishes to bond the resin to the glass when coupled with long time specimen boil-conditioning before testing. Under other circumstances, the specimen failure would not occur in an adhesive manner but by cohesive failure in the resin. Therefore, this test gives not only a number but an important insight into the mechanism of failure when coupled with appropriate specimen environmental conditioning. The horizontal shear strength may vary with specimen thickness, temperature, atmosphere conditions, and the differences in the rate of loading.

APPARATUS

4. (a) Testing Machine. - A properly calibrated testing machine which can be operated at constant rates of crosshead motion, and in which the error in the loading measuring system shall not exceed $\pm$ 1%. The load indicating mechanism shall be essentially free from inertial lag at the crosshead rate used. The accuracy of the testing machine shall be verified in accordance with the "Methods of Verification of Testing Machines (ASTM Designation: E4).

(b) Loading Nose and Support. - The loading nose and supports shall be in accordance with dimensions shown in Figure 2 (Note 1).

(c) Micrometers. - Suitable micrometers, reading to at least 0.025 mm (0.001 in.), for measuring the width, thickness, and span length of the test specimens.

5. The specimens shall be cut from a ring-type specimen conforming to the dimensions shown in Figure 4 (Note 2).

6. At least ten specimens shall be tested for each ring for determination of the horizontal shear.

7. (a) "Standard" Conditioning Procedure. - The test specimens shall be conditioned and tested in a room or enclosed space maintained at 23 $\pm$ 1° C (73.4 $\pm$ 1.8° F) and 50 $\pm$ 2 per cent RH in accordance with Procedure A of the "Methods of Conditioning Plastics and Electrical Insulating Materials for Testing" (ASTM Designation: D 618).

(b) If it is desired to test the effect of boiling water on the shear strength: The specimens shall be placed in boiling tap water for a prescribed period of time, then removed and placed in water at 23 $\pm$ 1° C (73.4 $\pm$ 1.8° C) for fifteen minutes. The specimens shall then be wiped dry and tested at the "standard" condition.

SPEED OF TESTING

8. The specimen shall be tested at a rate of crosshead movement of 1.27 millimeters per minute (0.05 inches per minute).

9. (a) Before conditioning or testing, measure the thickness and width of each specimen to the nearest 0.025 millimeter (0.001 inch) at the midpoint.

Note 1. - It has been found that a hardened steel dowel pin manufactured by the Producto Machine Company, Bridgeport, Connecticut, having a tolerance of 0.0025 mm ($\pm$ 0.0002 in.) is suitable.
Note 2. - The specimens shall be cut from the rings using a carborundum or diamond cutting wheel, which is water cooled. A suitable jig should be used to assure uniformity. The specimens shall be marked, with a suitable marking pen, for identification purpose.

(b) Place test specimen in test fixture, as shown in Figures 2 and 3. Align the specimen so that its midpoint is centered and its long axis is perpendicular to the cylindrical axis of the loading nose.

(c) Apply the load to the specimen (convex side) at the specified cross-head rate. Record the load to break specimen (maximum load on load indicating mechanism (Note 3)). Also record the position of shear (e.g., left, right, center, or complete delamination across specimen).

RETESTS

10. Values for properties at break shall not be calculated for any specimen that breaks at some obvious, fortuitous flaw, unless such flaws constitute a variable being studied. Retests shall be made for any specimen on which values are not calculated. If a specimen in the shear test failed in a manner other than shear, the value shall be discarded and retest shall be made.

11. (a) The shear strength shall be calculated from either of the following formulas:

$$S_H \frac{(\text{lbs})}{\text{in}^2} = \frac{0.75\ \rho_B\ (\text{lbs})}{bd\ (\text{in}^2)}, \text{ or } S_H(\text{kg}/_{\text{cm}}2) = \frac{0.0528\ \rho_B\ (\text{kgs})}{bd\ (\text{cm}^2)}$$

where

S_H = horizontal shear strength,

ρ_B = breaking load,

b = width of specimen,

d = thickness of specimen,

(b) Arithmetic Means for Each Series of Tests. - The arithmetic mean of all values obtained shall be calculated to three significant figures and reported as the "average value."

(c) Standard Deviation. - The standard deviation shall be calculated as follows and reported to two significant figures:

$$s = \frac{X^2 - n(\bar{X})^2}{n-1}$$

where

s = standard deviation

X = value of a single observation

Note 3. - A typical shear failure is characterized by a sharp audible report.

n = number of observations, and

X = arithmetic mean of the set of observation.

REPORT

14. The report should include the following:

(1) Complete identification of the material tested: include type, source, form, principal dimensions, and previous history.

(2) Conditioning procedure

(3) Thickness and width of the specimen

(4) Length of specimen

(5) Rate of crosshead motion in inches per minute

(6) Horizontal shear strength, average value and standard deviation

(7) Location of break

(8) Date of test.

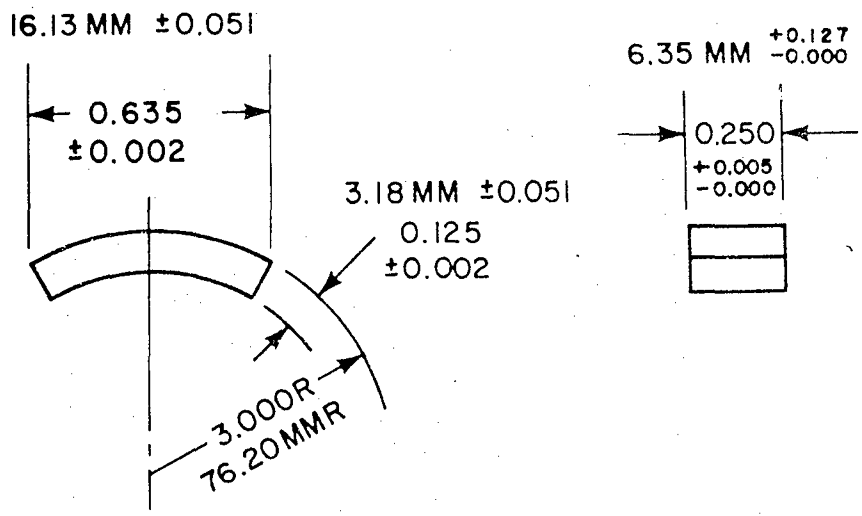


FIG. C-1 SHEAR TEST SPECIMEN

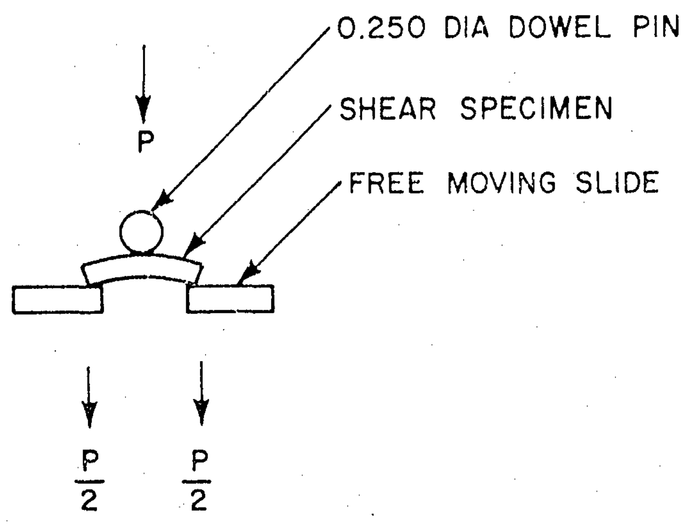


FIG. C-2 HORIZONTAL SHEAR LOAD DIAGRAM

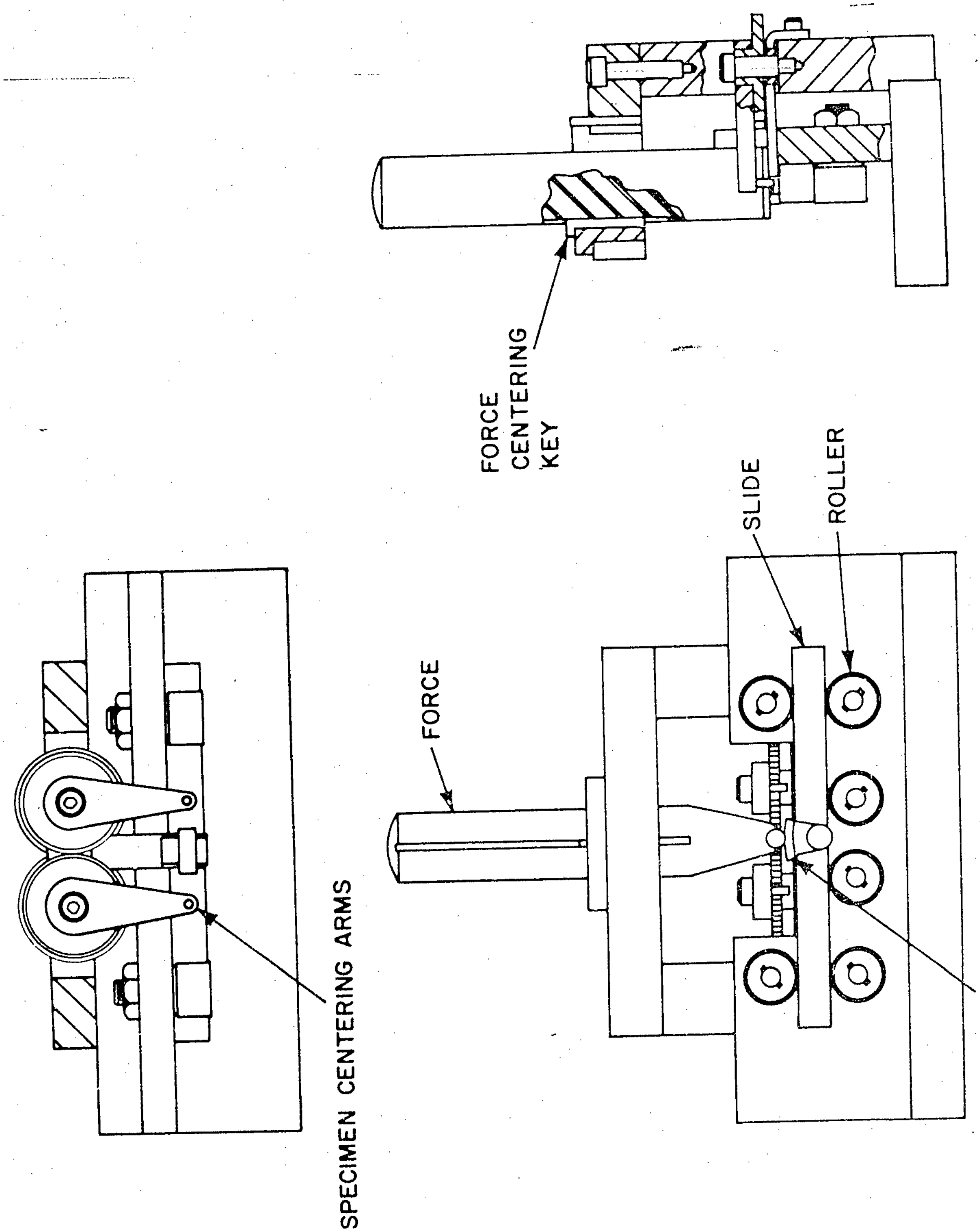
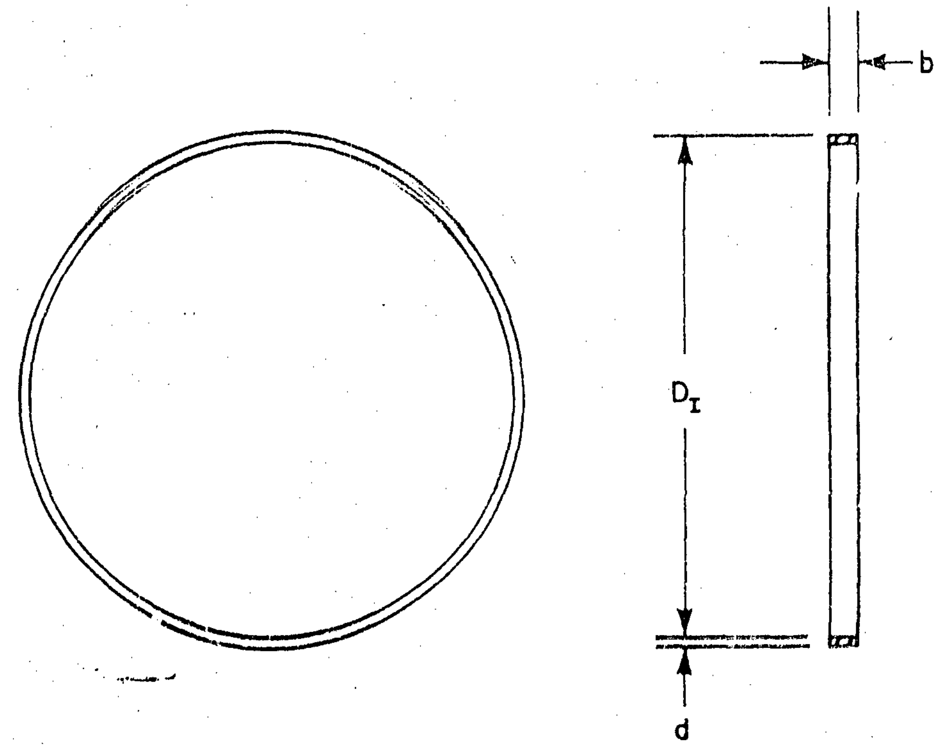


FIG. C-3 RING SHEAR TEST FIXTURE



D_I = 146.05 MM ±0.051 (5.750 IN. ±0.002)
b = 6.35 MM $^{+0.127}_{-0.000}$ (0.250 IN. $^{+0.005}_{-0.000}$)
d_s = 3.18 MM ±0.76 (0.125 IN. ±0.003) SHEAR
d_T = 1.52 MM ±0.076 (0.060 IN ±0.003) TENSILE-SPLIT DISC

FIG. C-4 RING TEST SPECIMEN

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	DESCRIPTORS	CODES		DESCRIPTORS	CODES
SOURCE	NOL technical report	NOLTR	SECURITY CLASSIFICATION AND CODE COUNT	Unclassified - 16	UØ16
REPORT NUMBER	64-156	Ø64156	CIRCULATION LIMITATION		
REPORT DATE	9 September 1964	Ø964	CIRCULATION LIMITATION OR BIBLIOGRAPHIC		
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DESCRIPTORS	CODES	DESCRIPTORS	CODES	DESCRIPTORS	CODES
Rings	RING	Reinforced	REIN		
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13. ABSTRACT

Methods have been developed for the evaluation of filament wound composite structures making use of NOL ring test specimens. A method of ring fabrication and techniques for determination of ring tensile strength and ring interlaminar shear strength have been standardized and are presented herein. References are also cited for flexural and compression tests now in use. These methods have all been found of value in making materials comparisons in research and development work and have also served as materials quality control techniques.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Test Methods						
NOL Rings						
Tensile Testing						
Shear Testing						
Plastics Fabrication						
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